by Joseph J. Carr

Open Channel

Noise Cancellation Techniques

Noise is bad. Whether you operate a radio receiver, or some piece of scientific or medical instrumentation, noise interferes with acquiring desired signals. After all, radio reception and other forms of signal acquisition are essentially a game of signal-to-noise ratio (SNR).

The actual values of the desired signal and noise signal are not nearly as important as their ratio. If the signal is not significantly stronger than the noise, then it will not be properly detected.

Getting rid of noise battering a signal is a major chore. Although there are a number of different techniques for overcoming noise, the method described herein can be called the "invert and obliterate" approach.

This same idea was used in a popular novel in which a cranky inventor created a dynamic stealth concept by placing antennas all over an aircraft to receive radar signals, invert them, and then retransmit them 180 degrees out of phase with the incident wave ... thereby causing cancellation.

The idea is also used in actual (not fictional) noise abatement systems in which microphones and loudspeakers are used to retransmit room noises 180 degrees out of phase with the incoming. According to reports I've heard, remarkable reductions in local noise are possible, although the technique tends to fall down over large areas.

Figure 1 shows the basic problem and its solution (cast in terms of radio reception). The signal from the main antenna is a mixture of the desired signal, and a locally generated noise signal. This noise signal is usually generated by the 60 Hz alternating current (AC) power lines, or machinery and appliances operating from the 60 Hz AC lines. The noise signal is not confined to 60 Hz, but will extend into the VHF region because of harmonic content.

The noise spikes will appear every 60 Hz from the fundamental frequency up to about 200 MHz or so, although the harmonics become weaker and weaker at progressively higher frequencies. But in the VLF bands (where they are often overwhelming), AM broadcast band (AM BCB), and medium wave shortwave bands, the noise signal can be tremendous. It will therefore cause a huge amount of interference.

The solution (also shown in Figure 1) is to invert the noise signal, and combine it with the signal from the main antenna. When the phase inverted noise signal combines with the noise signal riding on the main signal, the result is cancellation of the noise signal, leaving the resultant main signal. What is needed is a noise sense antenna, a means for inverting the noise signal, and a summing circuit.

Figure 2 shows a generic case that serves to illustrate the method for both radio reception and other forms of instrumentation. The signal source will be the main antenna in the case of radio reception. But in the case of scientific instruments, it might be some sort of sensor. In a medical case, it could be a human patient with either sensors or electrodes attached (as in an electrocardiogram).

The noise source is the local AC power lines or machinery that radiates a signal of some sort. If the noise signal is picked up by the noise source (or its connecting wires), then it will travel through amplifier A1 and cause interference. But the signal can also be picked up by a small sense antenna, and fed to an inverting amplifier (A2).

By definition, an inverting amplifier shifts the phase of the input signal 180 degrees, so when the inverted noise signal is applied to the summer it will cancel the noise component of the main signal. It might be necessary to provide some amplitude control in order to not replace the main noise signal with a new noise signal from A2.

The case of a radio receiver system is shown in Figure 3. The phase inversion and summation functions of Figure 2 are performed in a special noise cancellation bridge circuit. The main antenna is the antenna that is normally used with the receiver. It might be a dipole, vertical, beam, or just a random length of wire strung between two trees.

The noise sense antenna is optimized for pick-up of the noise source signal. One VLF radioscience observer told me via E-Mail that he uses a 36-inch whip antenna mounted on his roof as the noise sense antenna.

In some shortwave situations, the sense antenna is a 10 to 30 foot length of antenna wire running parallel to the power lines that are creating the noise. **CAUTION:** Under no circumstances should you allow the sense antenna to touch the AC power lines, even if it breaks and whips around in the wind. In

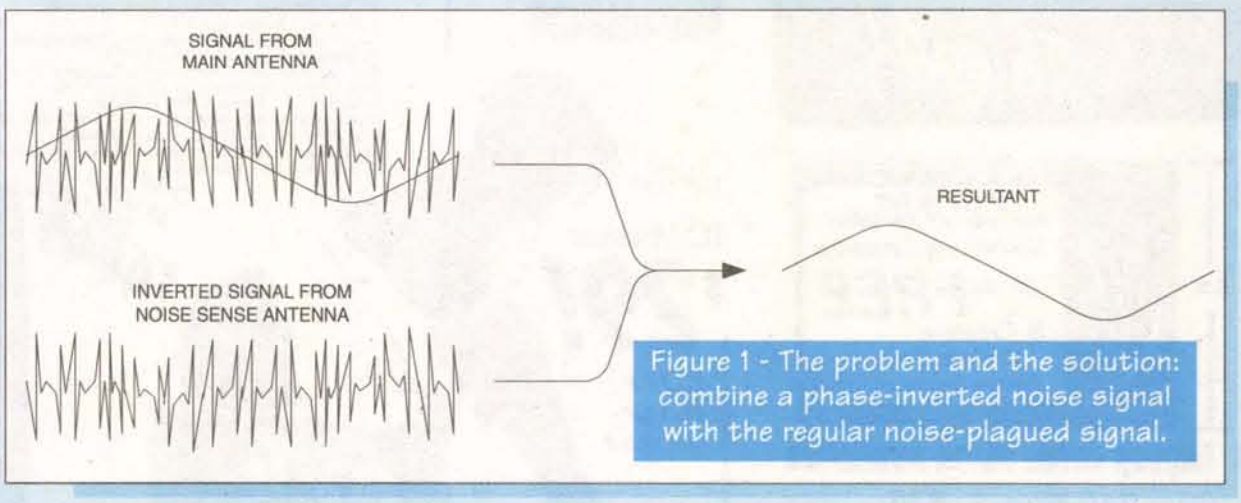

Figure 1 - The problem and the solution: combine a phase-inverted noise signal with the regular noise-plagued signal.

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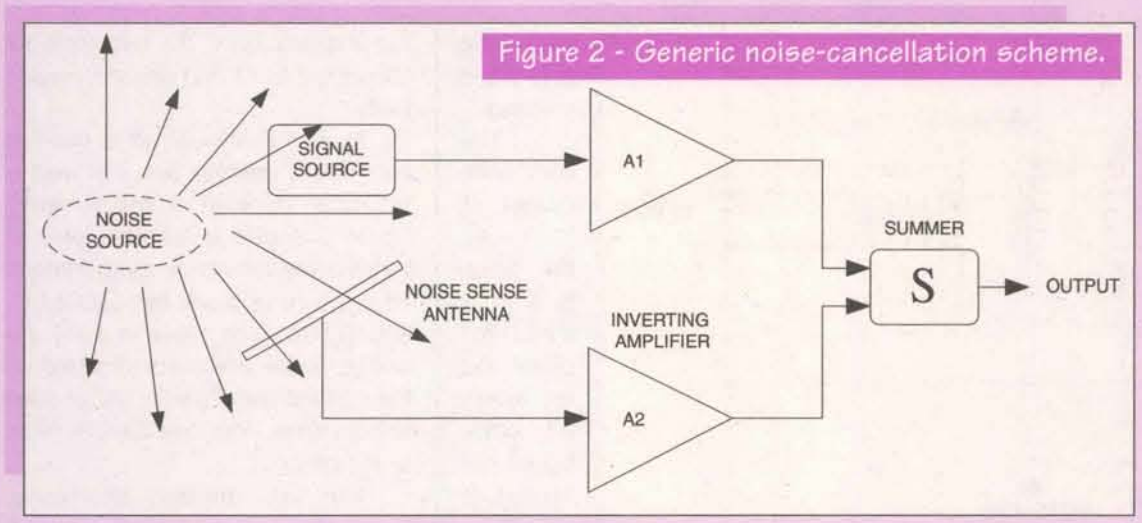

Figure 2 - Generic noise-cancellation scheme.

the case of VHF noise reception, the sense antenna might be a two or three element beam (Yagi or Quad) aimed at the noise source. Other combinations are also possible, I presume.

One goal of the sense antenna is to make it highly sensitive to the local noise field, while being a lot less sensitive to the desired signal than the main antenna. Although in purist terms, both noise and desired signals appear in both antennas, the idea is to maximize the noise signal and minimize the "desired" signal in the sense antenna, and do the opposite in the main antenna.

In the system in Figure 3, the noise sense signal and main signal are combined in a noise canceling bridge (NCB). The output of the NCB is a cleaned-up version of the antenna signal, with greatly improved SNR.

The design problems that must be overcome in producing the NCB are easy to see. First, it must either invert or provide other means for producing a 180-degree phase shift of the noise signal. It must also account for amplitude differences so that the inverted noise signal exactly cancels the noise component of the main signal.

If the amplitudes are not matched, then either some of the original noise component will remain, or the excess amplitude of the inverted noise signal will transfer to the signal and become interference in its own right. The noise signal inversion can be accomplished by transformers, bridge circuits, RLC phase shift networks, or delay lines.

A Simple Bridge Circuit

Figure 4 shows a simple bridge circuit. I've used it at VLF on radio-science observing receivers, and others have used it on VHF receivers. The bridge consists of two transformers (T1 and T2). Transformer T1 is trifilar wound, i.e., it has three identical windings interwound with each other in the manner of Figure 5. The black "phasing dots" or "sense dots" indicate one end of the windings, and will be used for wiring T1 into the circuit of Figure 2.

Winding the toroid exactly as shown in Figure 5 is a difficult task, so you might want to consider an alternative method. Select three lengths of enameled wire (#18 AWG through #26 AWG can be used, but all wires should be the same size). In order to keep them straight in my mind as I work them, I select three different insulation colors from my wire rack.

Tie all of them together at one end, and insert that end into the chuck of a hand drill. I usually fasten the other ends into a bench vice, and back off until the wires between the vice and drill are about straight (more or less). Turn on the drill at a slow speed (slightly squeeze the trigger on

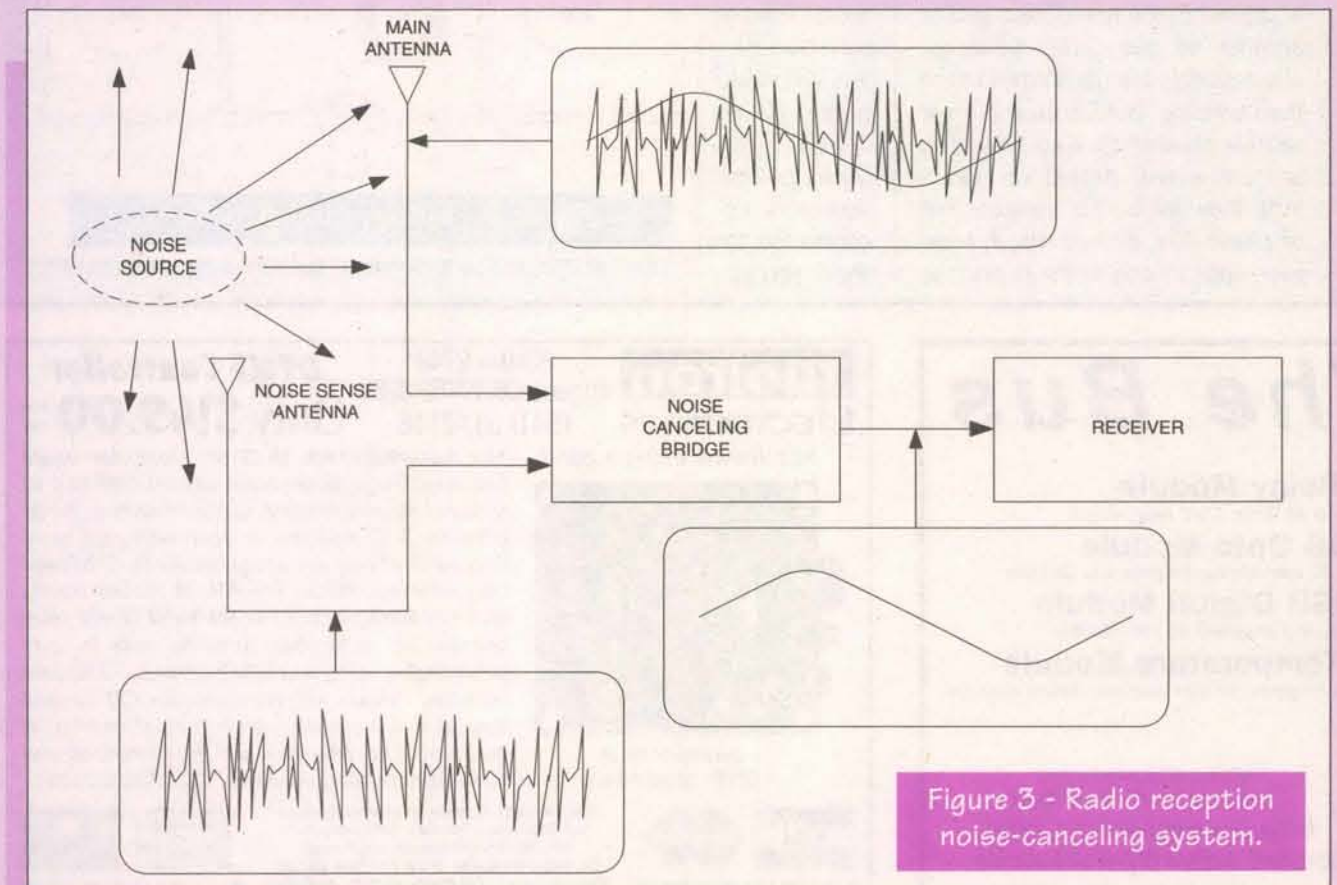

Figure 3 - Radio reception noise-canceling system.

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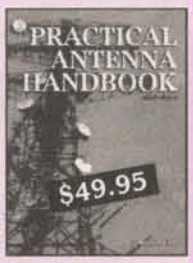

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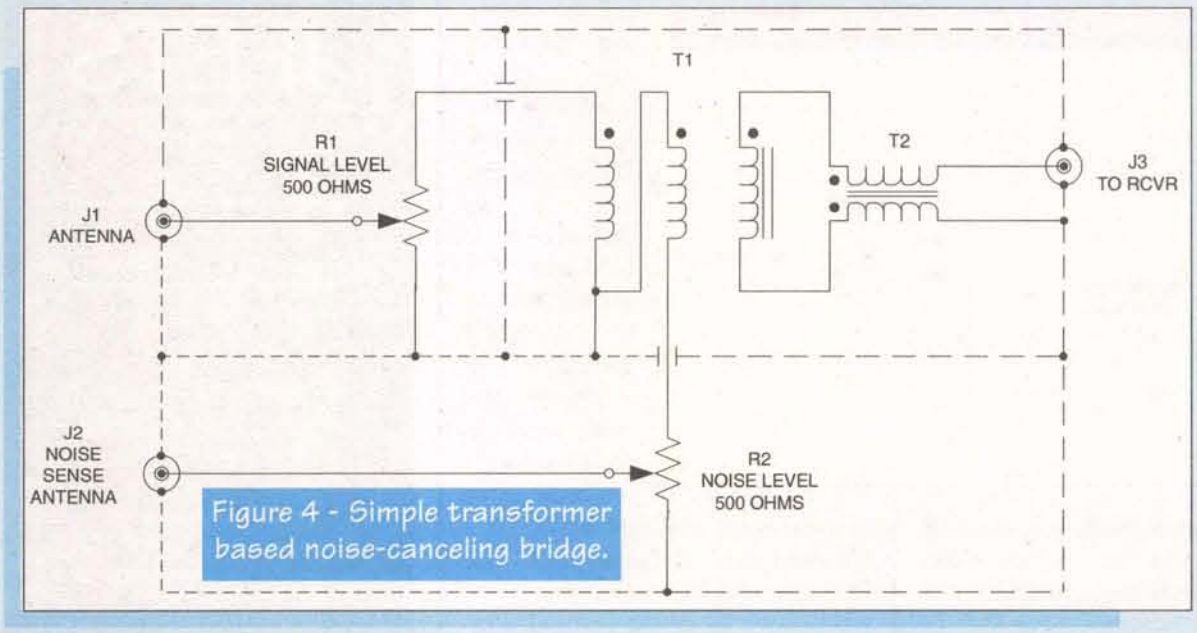

Figure 4 - Simple transformer based noise-canceling bridge.

variable speed drills), and let the drill twist them together. Keep this process going, being careful to not kink the wire (which happens easily!), until there are 8 to 16 twists per inch (not critical).

CAUTION: Wear protective goggles or safety glasses when doing this job. I once let the drill speed get too high; the wire broke and I received a nasty lashing to the face ... which could've damaged my eye except for the glasses.

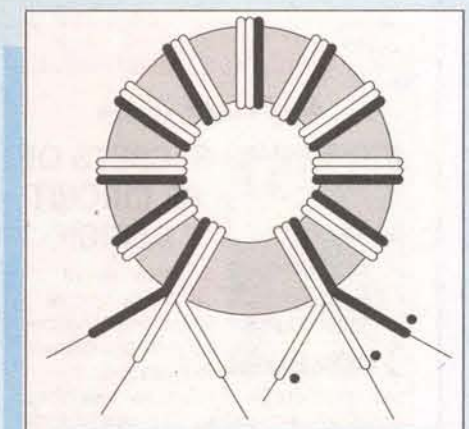

Figure 5 - Trifilar wound toroid transformer.

Once the three-wire composite wire is formed, it can be wound onto the toroid form as if it were one wire. Before winding, however, separate the ends a bit, scrape off enough insulation to attach an ohmmeter probe, and measure both the continuity of each wire, and whether or not any two are shorted together. If the wires are wound too tight, then it's possible to break one wire, or breech the integrity of the insulation.

Note in Figure 4 the way transformer T1 is wired. The main antenna signal from J1 is connected to the dotted end of one winding, while the sense antenna signal (J2) is applied to the non-dotted end of another of the three windings. These signals are transferred to the third winding, but because of their relative phasing (due to how they are connected, dotted or undotted), they will be 180 degrees out of phase. The desired signal, however, appears only in the J1 port, so will not be phase inverted.

The composite output of T1, i.e., the noise plus desired signal and the inverted noise signal, is applied to transformer T2. This transformer is inserted into the line as a common mode choke, so will perform the actual cancellation of the inverted and non-inverted noise signal components. Transformer T2 is built exactly like T1, but is bifilar (two windings) instead of trifilar.

Signal amplitudes from the two different antennas are controlled by a pair of 500-ohm potentiometers. The pots selected for R1 and R2 should be non-inductive (i.e., carbon or metal film, but NOT wirewound). In other words, rather ordinary potentiometers will work nicely. The wipers of both potentiometers are connected to their respective antenna jacks. The two ends are connected to T1 and ground, respectively.

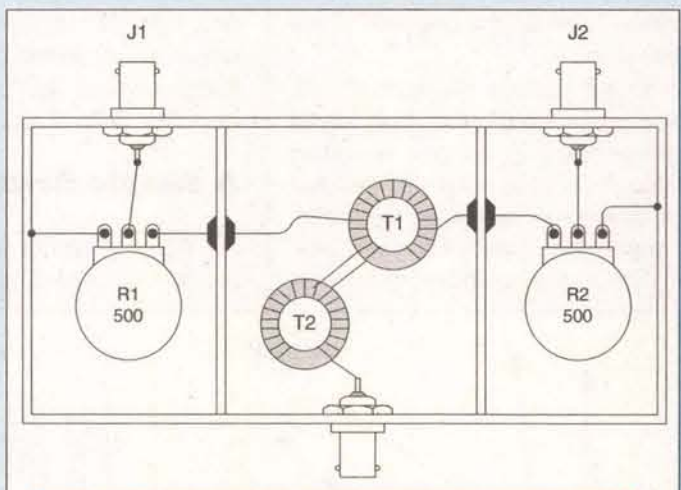

Figure 6 - Shielded construction.

Note that this circuit is not just built into a shielded box, but also in separate shielded compartments. Figure 6 shows a suitable form of building the circuits. A compartmented box such as made by SESCOM (1-800-634-3457) is used to hold the bridge. Small grommets mounted on the internal shield partitions are used to pass wires from one compartment to the other.

For VLF through shortwave, transformer T1 is wound with 16 turns of enameled wired, and T2 is wound with 18 turns. Both can be wound on half-inch cores (T-50-xx or FT-50-xx), but it will be easier to use slightly larger forms such as FT-68-xx, T-68-xx, FT-82-xx, and T-82-xx. Ferrite cores (FT-nn-xx) should be used in the AM BCB and below, while powered iron (T-nn-xx) can be used in the medium wave and shortwave bands.

Recommended ferrite types for VLF through the AM BCB include FT-82-75 and FT-82-77, medium wave units can be made using FT-82-61,

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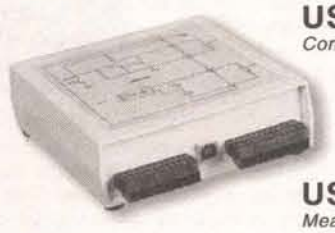

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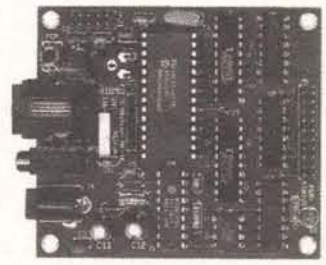

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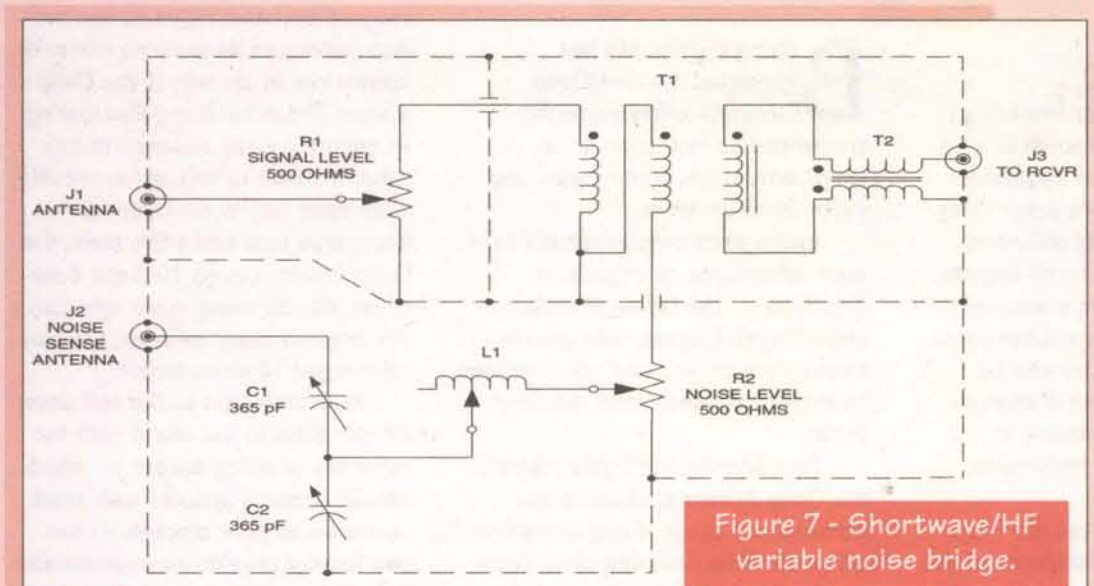

Figure 7 - Shortwave/HF variable noise bridge.

T1: 16 turns, #18 AWG Trifilar wound on Amidon FT-82-61 core
T2: 18 turns, #18 AWG, Bifilar wound on Amidon FT-82-61 core
L1: 32 uH, 45 turns, #22 enameled wire, 1-inch diameter, wire-dia. spaced
R1,R2: 500-ohms, non-inductive
C1,C2: 365 pF trimmer capacitors

A Different Bridge

A somewhat different approach to the bridge concept is shown in Figure 8.

L1A: 12 turns #22 AWG solid bare wire, one-inch diameter, wound over two-inches length.

L1B: Five turns spaced one diameter apart, #22 AWG solid bare wire, wound over center of L1A (a layer of insulating black electrical tape must separate the two coils).

The potentiometers are 500-ohm, linear tape, non-inductive pots of the type also specified for Figure 4. This bridge is tricky to balance as it involves the interaction of R1, R2, C1, C2, C3, L1A, and L1B. In some cases, one or both potentiometers must be shorted out to allow signal to pass unimpeded. In other cases, some value of R1 or R2 may be needed to balance amplitudes. Adjust all components iteratively until the best signal-to-noise ratio is obtained.

Parts can be a little difficult to obtain for RF projects, especially the capacitors. Ocean State Electronics [6 Industrial Drive, P.O. Box 1458, Westerly, RI 02891; 401-596-3080 or FAX 401-596-3590] stocks both new and used variable capacitors, as well as various inductors, toroid cores, and other items of interest.

Conclusion

Radiated noise can be one of the most intractable electromagnetic interference (EMI) problems. These bridges are not a "silver bullet" by any means, but they will perform sufficient noise reduction to make a significant difference in the signal-to-noise ratio ... and that's what actually counts. **NV**

and VHF units can be made using FT-67 or FT-68 (or their -50 and -68 equivalents). If powdered iron cores (T-nn-xx) are used, then select T-80-26 (YEL/WHT) for VLF, T-80-15 (RED/WHT) for AM BCB and low medium wave, either T-80-2 (RED) or T-80-6 (YEL) for medium wave to shortwave, and T-80-12 (GRN/WHT) for VHF. Again, their -50 and -68 equivalents are also usable. Some experimentation might be needed in specific cases depending on the local noise problem.

Figure 7 shows a version of the noise cancellation bridge circuit made popular by William Orr (W6SAI) and William R. Nelson (WA6FQG) for amateur radio use (*Interference Handbook*, RAC Publications, P.O. Box 2013, Lakewood, NJ 08701). It is built on the same principles as Figure 4, but includes an L-C phase shift network consisting of L1, C1, and C2. The values are:

- T1: 16 turns, #18 AWG trifilar wound on Amidon
- FT-82-61 core
- T2: 18 turns, #18 AWG, bifilar wound on Amidon
- FT-82-61 core
- L1: 32 uH, 45 turns, #22 enameled wire, 1-inch diameter, wire-diameter spaced
- R1,R2: 500-ohms, non-inductive linear taper potentiometer
- C1,C2: 365 pF capacitors

The coil L1 should be wound with either enameled wire or non-insulated solid wire so that it can be tapped.

To adjust this bridge, C1, C2, and the tape on L1 should be adjusted iteratively until the lowest possible noise signal is achieved. To do this trick, it is usually necessary to set R1 and R2 to a low setting, but not so low that both the noise and the signal disappear.

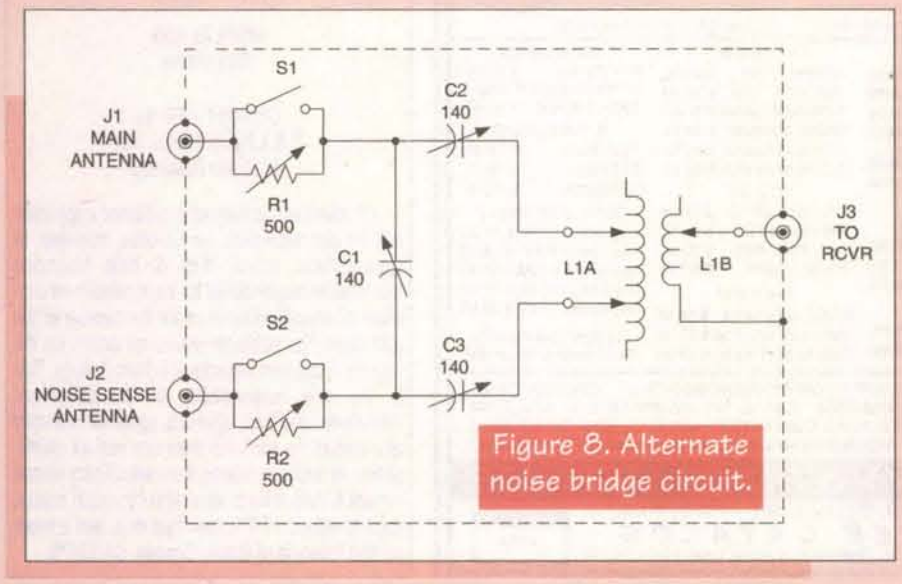

Figure 8. Alternate noise bridge circuit.

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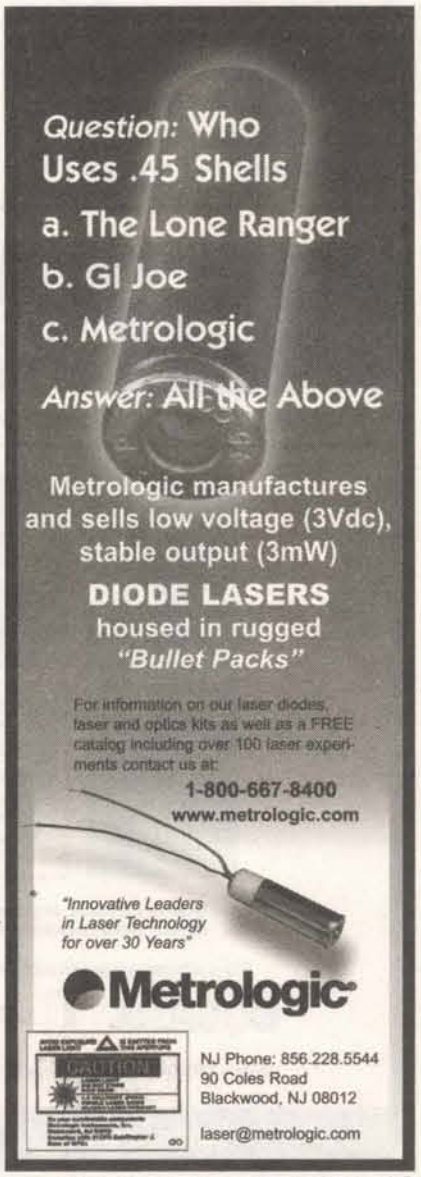
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